

# **CONVERGING TECHNOLOGIES FOR IMPROVING HUMAN PERFORMANCE: NANOTECHNOLOGY, BIOTECHNOLOGY, INFORMATION TECHNOLOGY AND COGNITIVE SCIENCE**

## *Table of Contents*

<b>EXECUTIVE SUMMARY .....</b>	ix
--------------------------------	----

<b>OVERVIEW.....</b>	<b>1</b>
1. Background.....	1
2. Timely and Broad Opportunity.....	2
3. Vision for Enhancing Human Abilities and Societal Performance.....	4
4. Strategies for Transformation .....	7
5. Towards Unifying Science and Converging Technology .....	9
6. Major Themes.....	12
7. Future Prospects.....	14
8. Recommendations.....	20

<b>GENERAL STATEMENTS AND VISIONARY PROJECTS .....</b>	<b>25</b>
--	-----------

<b>A. MOTIVATION AND OUTLOOK.....</b>	<b>25</b>
---------------------------------------	-----------

### **Theme A Summary**

Panel: P. Bond, J. Canton, M. Dastoor, N. Gingrich, M. Hirschbein, C.H. Huettner, P. Kuekes, J. Watson, M.C. Roco, S. Venneri, R.S. Williams.....	25
--	----

### **Statements**

National Strategy towards Converging Science and Technology (C.H. Huettner) .....	27
Converging Technologies and Competitiveness (P. Bond).....	28
Vision for the Converging Technologies (N. Gingrich).....	31
Zone of Convergence Between Bio/Info/Nano Technologies: NASA's Nanotechnology Initiative (S. Venneri, M. Hirschbein, M. Dastoor) .....	48
Biomedicine Eyes 2020 (J. Watson).....	51
Balancing Opportunities and Investments for NBIC (R.S. Williams, P. Kuekes).....	58
The Impact of Convergent Technologies and the Future of Business and the Economy (J. Canton,) .....	61
Coherence and Divergence of Megatrends in Science and Engineering (M.C. Roco)....	69

***B. EXPANDING HUMAN COGNITION AND COMMUNICATION ..... 85*****Theme B Summary**

Panel: W.S. Bainbridge, R. Burger, J. Canton, R. Golledge, R.E. Horn, P. Kuekes, J. Loomis, C.A. Murray, P. Penz, B.M. Pierce, J. Pollack, W. Robinett, J. Spohrer, S. Turkle, L.T. Wilson .....	85
--	----

**Statements**

NBICS (Nano-Bio-Info-Cogno-Socio) Convergence to Improve Human Performance: Opportunities and Challenges (J. Spohrer).....	89
Sensor System Engineering Insights on Improving Human Cognition and Communication (B.M. Pierce) .....	102
Can Nanotechnology Dramatically Affect the Architecture of Future Communications Networks? (C.A. Murray) .....	104
Spatial Cognition and Converging Technologies (R. Golledge) .....	106
Visual Language and Converging Technologies in the Next 10-15 Years (and Beyond) (R.E. Horn) .....	124
Sociable Technologies: Enhancing Human Performance when the computer is not a tool but a companion (S. Turkle).....	133

**Visionary Projects**

Socio-tech...the Predictive Science of Societal Behavior (G. Yonas, J. Glicken Turnley).....	140
Breaking the Limits on Design Complexity (J. Pollack) .....	143
Enhancing Personal Area Sensory and Social Communication Through Converging Technologies (R. Burger) .....	146
The Consequences of Fully Understanding the Brain (W. Robinett) .....	148
User-Interface Olympics: Using Competition to Drive Innovation (W. Robinett).....	151
Accelerating Convergence of Biotechnology, Nanotechnology, & Information Technology (L.T. Wilson).....	154

***C. IMPROVING HUMAN HEALTH AND PHYSICAL CAPABILITIES ..... 159*****Theme C Summary**

J. Bonadio, L. Caulier, B. Chance, P. Connolly, E. Garcia-Rill, R. Golledge, M. Heller, P.C. Johnson, K.A. Kang, A.P. Lee, R.R. Llinas, J.M. Loomis, V. Makarov, M.A.L. Nicolelis, L. Parsons, A. Penz, A.T. Pope, J. Watson, G. Wolbring.....	159
---	-----

**Statements**

Nanobiotechnology and Life Extension (P. Connolly) .....	162
The Nano-Bio Connection and Its Implication for Human Performance (M. Heller) ....	169
Gene Therapy: Reinventing the Wheel or Useful Adjunct to Existing Paradigms? (J. Bonadio) .....	171
Implications of the Continuum of Bioinformatics (P.C. Johnson).....	183
Sensory replacement and sensory substitution: Overview and prospects for the future (J.M. Loomis) .....	189
Vision Statement: Interacting Brain (B. Chance, K.A. Kang) .....	199
Focusing the possibilities of Nanotechnology for Cognitive Evolution and Human Performance (E. Garcia-Rill).....	201
Science and Technology and the Triple D (Disease, Disability, Defect) (G. Wolbring)	206

## **Visionary Projects**

Brain-Machine Interface via a Neurovascular Approach (R. Llinás, V. Makarov).....	216
Human-Machine Interaction: Potential Impact of Nanotechnology in the Design of Neuroprosthetic Devices Aimed at Restoring or Augmenting Human Performance (M. Nicolelis).....	223
Nanotechnology: The Merging of Diagnostics and Treatment (A.P. Lee).....	226
Artificial Brains and Natural Intelligence (L. Cauiller, A Penz) .....	227
Converging Technologies for Physiological Self-regulation (A.T. Pope, O. Palsson)... 231	
Improving Quality of Life of Disabled People using Converging Technologies (G. Wolbring, R. Golledge).....	240
<b>D. ENHANCING GROUP AND SOCIETAL OUTCOMES .....</b>	<b>243</b>

## **Theme D Summary**

Panel: J.S. Albus, W.S. Bainbridge, J. Banfield, M. Dastoor, C.A. Murray, K. Carley, M. Hirshbein, T. Masciangioli, T. Miller, R. Norwood, R. Price, P. Rubin, J. Sargent, G. Strong, W.A. Wallace.....	243
---	-----

## **Statements**

Cognition, Social Interaction, Communication and Convergent Technologies (P. Rubin) .....	245
Engineering the Science of Cognition to Enhance Human Performance (W.A. Wallace) .....	248
Engineering of Mind for Enhancing Human Productivity (J.S. Albus).....	249
Making Sense of the World: Convergent Technologies for Environmental Science (J. Banfield).....	260

## **Visionary Projects**

The Communicator: Enhancement of Group Communication, Efficiency and Creativity (P. Rubin, M. Hirschbein, T. Masciangioli, T. Miller, C. Murray, R. Norwood, J. Sargent).....	265
Enhanced Knowledge-Based Human Organization and Social Change (K. Carley) ....	270
A Vision for the Aircraft of the 21st Century (S. Venneri, M. Hirschbein, M. Dastoor).....	275
Memetics: A Potential New Science (G. Strong, W.S. Bainbridge).....	279

<b>E. NATIONAL SECURITY .....</b>	<b>287</b>
-----------------------------------	------------

## **Theme E Summary**

Panel: R. Asher, D.M. Etter, T. Fainberg, M. Goldblatt, C. Lau, J. Murday, W. Tolles, G. Yonas.....	287
--	-----

## **Statements**

Cognitive Readiness: An Important Research Focus for National Security (D.M. Etter).....	289
DARPA's Programs in Enhancing Human Performance (M. Goldblatt) .....	297
NBIC for Homeland Defense: Chemical/Biological/Radiological/Explosive (CBRE) Detection/Protection (J. Murday).....	301
Future Roles for Science and Technology in Counterterrorism (T. Fainberg) .....	303
Nanotechnology and the Department of Defense (C. Lau).....	308

Advanced Military Education and Training (J. Murday).....	309
<b>Visionary Projects</b>	
High-performance Warfighter (J. Murday).....	311
Non-Drug Treatments for Enhancement of Human Performance (R. Asher).....	313
Brain-Machine Interface (R. Asher) .....	315
Nano-Bio-Info-Cogno as Enabling Technology for Uninhabited Combat Vehicles (C. Lau) .....	317
Data Linkage and Threat Anticipation Tool (T. Fainberg).....	318
<b>F. UNIFYING SCIENCE AND EDUCATION.....</b>	<b>321</b>
<b>Theme F Summary</b>	
Panel: D.L. Akins, Y. Bar-Yam, J.G. Batterson, A.H. Cohen, M.E. Gorman, M. Heller, J. Klein-Seetharaman, A.T. Pope, M.C. Roco, R. Reddy, W. Tolles, R.S. Williams, D. Zolandz .....	321
<b>Statements</b>	
Combining the Social and the Nanotech: A Model for Converging Technologies (M.E. Gorman) .....	325
Breadth, Depth and Academic Nano-Niches (W. Tolles).....	330
Unifying Principles in Complex Systems (Y. Bar-Yam).....	335
Mind Over Matter in an Era of Convergent Technologies (D.L. Akins).....	361
Converging Technology and Education for Improving Human Performance (A.H. Cohen) .....	363
<b>Visionary Projects</b>	
Converging Technologies: A K-12 Education Vision (J.G. Batterson, A.T. Pope).....	367
Expanding the Trading Zones for Convergent Technologies (M. Gorman) .....	374
Biological Language Modeling: Convergence of computational linguistics and biological chemistry (J. Klein-Seetharaman, R. Reddy) .....	378
<b>APPENDICES</b>	
<b>A. List of Participants and Contributors .....</b>	<b>387</b>
<b>B. Index of Authors.....</b>	<b>392</b>
<b>C. Index of Topics .....</b>	<b>404</b>